Developing Graphene Foil Technology for Instruments Targeting Low-Energy Ring Current Populations at Earth

Completed Technology Project (2018 - 2021)

Project Introduction

The goal of this proposal is to develop graphene foil technology to the point where these foils can be readily used in energetic neutral atom (ENA) and plasma instruments in space that employ thin carbon foils. The science question targeted by this technology development is "What is the contribution from Coulomb collisions to plasma loss from the Earth's ring current?" Coulomb collisions between ring current ions and thermal populations in the plasmasphere are believed to produce a source of low energy (< 500 eV) ions to the Earth's inner magnetosphere during both quiet and active times. The ENAs produced from these low energy ions are difficult to measure with current ENA instruments because of their very low probability of being transmitted through the thin carbon foils (~0.5 ug cm^-2 or ~100 atomic layers) currently in use. The recent development of graphene, a two-dimensional carbon material where the atoms are tightly packed into a honeycomb lattice, has opened the possibility of making much thinner foils (few atomic layers) and, therefore, expanding the energy range of ENA imagers to colder particles. Developing this new technology can make it possible to remotely observe Coulomb-collision-generated sub-keV ring current populations via ENA imaging, along with low energy ENA populations from other sources. To achieve our goal, we propose the following three objectives, 1. Develop large area (> 1 cm^2), single crystal graphene foils with controllable thickness (3 - 5 atomic layers). 2. Characterize the properties of large area, single crystal graphene foils and their response to vibrational, thermal, and acoustic stresses. 3. Compare the performance of large area, single crystal graphene and thin carbon foils in a prototype ENA instrument. The graphene foils used in this project will be produced at Texas State University by Co-I Dr. Qingkai Yu. We will use polymer-assisted transfer of graphene from the copper substrate to electroformed nickel grids. The angular scattering and energy straggling of ions passing through the graphene foils will be measured using existing experimentsin the Ion Calibration Facility at Southwest Research Institute (SwRI). An experiment for measuring secondary electron emission will be built based on a setup built previously by Co-I Allegrini. Testing graphene and thin carbon foil performance in a prototype ENA instrument will be accomplished using an engineering model of the Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS). All facilities, experiments, and instruments are available to this project. Our proposal directly responds to the NASA-ROSES 2017 H-TIDeS AO by developing technologies to enable the measurement of sub-keV ring current populations at Earth using ENA sensors. This new capability directly supports the science question "How are magnetospheric and ionospheric plasma transported and accelerated by solar wind forcing and magnetosphere-ionosphere coupling?" of the Magnetospheric Energetics, Dynamics, and Ionospheric Coupling (MECIDI) mission concept. MEDICI is a Solar Terrestrial Probes class mission that was recommended for implementation in the 2012 Decadal Strategy for Solar and Space Physics. The technologies developed here will also lead to measurements that respond to two key NASA Heliophysics Science goals, (1)

Developing Graphene Foil Technology for Instruments Targeting Low-Energy Ring Current Populations at Earth

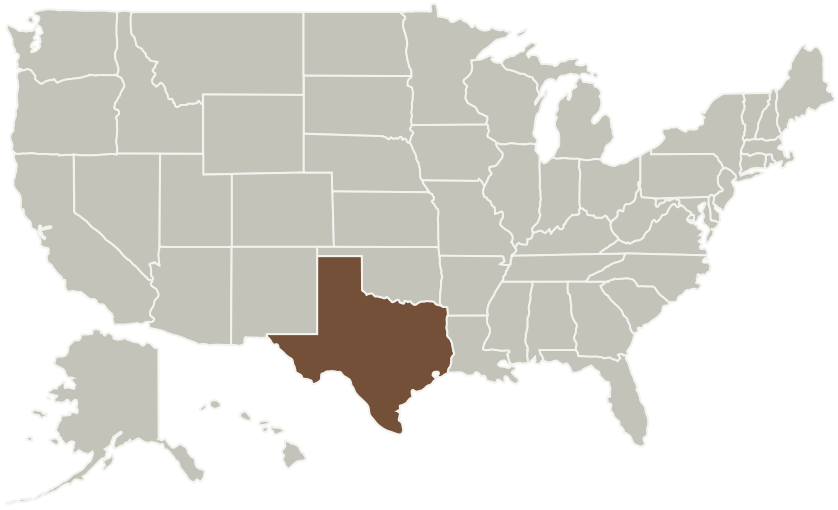
Table of Contents

Developing Graphene Foil Technology for Instruments Targeting Low-Energy Ring Current Populations at Earth

Completed Technology Project (2018 - 2021)

Explore the physical processes in the space environment from the Sun to the Earth and throughout the solar system, and (2) Advance our understanding of the connections that link the Sun, the Earth, planetary space environments, and the outer reaches of our solar system.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Southwest Research Institute - San Antonio(SWRI)	Lead Organization	Academia	San Antonio, Texas
Texas State University	Supporting Organization	Academia Hispanic Serving Institutions (HSI)	San Marcos, Texas

Primary U.S. Work Locations
Texas

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

Southwest Research Institute - San Antonio (SWRI)

Responsible Program:

Heliophysics Technology and Instrument Development for Science

Project Management

Program Director:

Roshanak Hakimzadeh

Program Manager:

Roshanak Hakimzadeh

Principal Investigator:

Robert W Ebert

Co-Investigators:

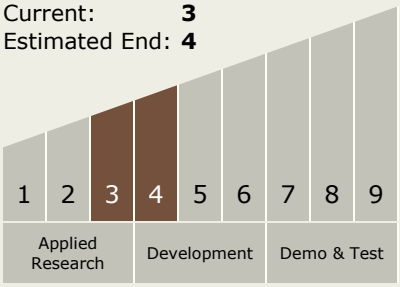
Ronald B Kalmbach
Qingkai Yu
Frederic Allegrini

Developing Graphene Foil Technology for Instruments Targeting Low-Energy Ring Current Populations at Earth

Completed Technology Project (2018 - 2021)

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **4**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.1 Remote Sensing Instruments/Sensors
    - TX08.1.1 Detectors and Focal Planes

Target Destination

The Sun